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01- 2401 JC14 Rec'd PCT/PTO 19 JAN 2002 CT

FORMS PTO-1390 (REV 10-96) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER SI01-013 U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/031899
INTERNATIONAL APPLICATION NO. PCT/DE00/02399	INTERNATIONAL FILING DATE July 21, 2000	PRIORITY DATE CLAIMED July 21, 1999
TITLE OF INVENTION OPTICAL COUPLING DEVICE		
APPLICANT(S) FOR DO/EO/US Corning Incorporated		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C.371.
3. ☐ This express request to being national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. To 16. Below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An Assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: - Original Translation of PCT Application
    -Version of Application With Markings to Show Changes Made
    -**CLEAN** Version of Amended Application, to be used for examination purposes

10031899 PCT/PTO 19 JAN 2002

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
10/031899	PCT/DE00/02399	SI01-013

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a)(1)-(5):		
Neither international preliminary examination fee (37 DFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO....................... **$1040.00**		
International preliminary examination fee (37 CFR 1 482) not paid to USPTO but International Search Report prepared by the EPO or JPO..................... **$890.00**		
International preliminary examination fee (37 CFR 1 482) not paid to USPTO but international search fee (37 CFR 1 445(a)(2)) paid to USPTO........................... **$740.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33 (1)-(4) **$710.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)............................ **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	12 ~~10~~ - 20 =	0	X $18.00	$.00	
Independent claims	2 - 3 =	0	X $84.00	$.00	
MULTIPLE DEPENDANT CLAIM(S) (if applicable)			+ $270.00	$	

TOTAL OF ABOVE CALCULATIONS =	$890.00	
Reduction of ½ for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) +	$	
SUBTOTAL =	$890.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$890.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$	
TOTAL FEES ENCLOSED =	$.00	

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1 10 on the date indicated below and is Addressed to the Commissioner of Patents and Trademarks, Washington, DC 20231

on 1/19/02 By: Bethany Beligotti
(Date) Signature. Bethany J Beligotti

"EXPRESS MAIL" Mailing Label No. EV041470803US

Amount to be refunded:	$
Charged:	$890.00

a. ☐ A check in the amount of $ _____ to cover the above fees is enclosed.

b. ☒ Corning Incorporated hereby authorizes use of **Deposit Account No. 03-3325** in the amount of $ 890.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 03-3325. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:
Walter M. Douglas
Corning Incorporated
SP-TI-03
Corning, NY 14831

Walter M. Douglas
Signature

Registration No.: 34,510
(607) 974-2431

10031899 . 10/031899
JC13 Rec'd PCT/PTO 19 JAN 2002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor: Gervin Ruegenberg et al.

Serial No: TBA

Filing Date: Herewith

Title: OPTICAL COUPLING DEVICE

Art Group Unit: TBA

Examiner: TBA

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

PRELIMINARY AMENDMENT

After receipt of the application and prior to the calculation of the filing fees for the application, applicants respectfully request the entry of this amendment.

The Commissioner is hereby authorized to charge any fees due for the filing of this application or the entry of this amendment to Deposit Account No. 03-3325

Prior to examination of the above captioned application and issuing an office action on the merits, please enter this amendment, as set forth below.

IN THE SPECIFICATION

Please see attached application entitled "Clean Version of Amended Application".

IN THE CLAIMS

Please see attached application entitled "Clean Version of Amended Application".

REMARKS

This application is a national stage filing under 35 U.S.C. § 371 of PCT Application No. PCT/DE00/02399, filed July 21, 2000, which was filed in the German language, and which claimed the priority of German National Application No. 19934185.0. Enclosed herewith please find a copy of the application translated into English as received from the translating party, entitled "Original Translation". Also enclosed please find a copy of the application as amended with additions underlined and deletions in brackets, which application is entitled "Version of Application with Markings to Show Changes Made". Finally, enclosed please find a clean copy of the application as amended, entitled "Clean Copy of Amended Application". Applicants enclose copies of the complete application to show the changes made and a clean copy of the complete application because under the new rules, we would have had to replace almost every paragraph in the application in this Preliminary Amendment. Applicants believe that no new subject matter has been added to the application.

Applicants respectfully that all amendments made herein be duly entered into the application. If there are any question, please contact applicants' undersigned attorney.

Conclusion

Based upon the above amendments and remarks, Applicants believe the pending claims of the above-captioned application are in allowable form and patentable. Applicants respectfully request consideration of the application as amended and a prompt Notice of Allowance thereon.

Applicants believe that no extension of time is necessary to file this Preliminary Amendment. Should Applicants be mistaken, Applicants respectfully request that the Office grant such time extension pursuant to 37 C.F.R. § 1.136(a) as necessary to make this amendment timely, and hereby authorizes the Office to charge any necessary fee or surcharge with respect to said time extension to the deposit account of the undersigned firm of attorneys, Deposit Account 03-3325.

Please direct any questions or comments to Walter M. Douglas at (607) 974-2431.

Respectfully submitted,

CORNING INCORPORATED

Date: Jan 18, 2002

Date of Deposit: 1/19/02

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date indicated above with sufficient postage as first class mail in an envelope addressed to the. Commissioner of Patents and Trademarks, Washington, DC 20231

Signature Bethany Beligotti

Walter M. Douglas
Registration No. 34,510
Corning Incorporated
Patent Department
Mail Stop SP-TI-03-1
Corning, NY 14831

CLEAN VERSION OF AMENDED APPLICATION

SI01-013

OPTICAL COUPLING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of German Patent Application No. 19934185.0 filed July 21, 1999, and is a national stage filing under 35 U.S.C. § 371 of PCT Application PCT/DE00/02399, filed July 21, 2000.

FIELD OF THE INVENTION

[0002] The invention relates to an optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of a strip conductor of an optical component, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding element and is connected to the structure containing the other optical waveguide, or is fixed to said structure, by means of at least one holding block.

BACKGROUND OF THE INVENTION

[0003] An optical coupling device is disclosed, for example, by WO 98/13718. Coupling devices of this type are used in optical filters based on the phased-array principle having an input coupling face which light enters at a specific geometric position, the geometric position influencing the output wavelength of the optical filter. Optical filters based on the phased-array principle are used in particular as multiplexers or demultiplexers in optical wavelengths multiplex operation (WDM), since they exhibit low insertion attenuation and high crosstalk suppression.

[0004] German patent application DE 44 22 651.9 describes how the centre wavelength of a phased-array filter can be defined by the position of an input coupling optical waveguide which leads the light into the optical waveguide. In this way, the centre wavelength of the optical filter can be adjusted exactly by means of the geometric positioning of the input coupling optical waveguide or the input coupling fibre.

[0005] Optical coupling devices are also used in narrow-band wavelength multiplexers (DWDM) for optical waveguide transmission technology. These components make it possible, on the transmitter side, to combine the signals from lasers of various wavelengths with low losses onto a single glass fibre or, respectively, on the receiver side, to divide said

signals to a corresponding number of receivers in a wavelength-selective manner.

[0006] The particular advantage of narrow-band wavelength multiplexers as compared with conventional wavelength multiplexers lies in their narrow-band nature. As a result, such a small channel spacing is possible that, at the minimum attenuation of the glass fibre, that is to say in the wavelength range around 1550 nm, a large number of transmission channels, for example 32 transmission channels, can be accommodated. A DWDM comprises a chip, to which waveguide structures with the necessary geometry are applied. On the receiver side, the input of the chip is the fibre with the multiplexer signal, which is also referred to as the input coupling fibre. On the output coupling side, a corresponding number of fibres are fitted, which lead the individual signals on to the receiver.

[0007] In optical waveguide transmission technology with DWDM, the problem is that the characteristics of the chip change sharply with the operating temperature. A temperature change leads to a change in the refractive index relationships and also the geometric relationships of the chips. As a result, wavelength shifts occur, that is to say the branch of the channel between DWDM and the lasers and, respectively, between the transmitter side and the receiver side is shifted. For this reason, the shift in the centre wavelengths must be avoided.

[0008] In order to avoid the temperature effects described, passive temperature compensation has already been proposed. The temperature dependence of the centre wavelength can be compensated for by the fact that the input coupling fibre is shifted vertically with respect to the DWDM chip as a function of the temperature. This shift is carried out by means of a variable-length component which, as compared with the carrier material of the chip, has a higher thermal coefficient of expansion, for example by means of a variable-length element made of aluminium. Then, as was described at the beginning, the optical fibre is fixed to the variable-length element, so that the end faces of the optical fibre and of the optical conductor chip (also called a planar waveguide or a planar waveguide chip) are shifted parallel to one another, which compensates for the influence of the temperature on the centre wavelength.

[0009] In the practical implementation of this coupling device, the connecting points between the holding block and the chip, on the one hand, and the holding block and the variable-length element, on the other hand, are designed using adhesive bonding technology. In this case, the bonding point between the holding block and the chip is cured after the input coupling fibre has been positioned optically relative to the chip.

[0010] In the case of this technology, the problem arises that the bonded connections are subject to temperature-dependent changes. As a result of different bond gap widths, inhomogeneities and gassing-out of the adhesive, mechanical stresses arise in the gap. This is particularly critical in the case of bonded connections between materials with different coefficients of thermal expansion, such as aluminium and glass or glass ceramic. The consequence of the thermally inducted stresses is that a temperature change not only affects the desired movement of the end faces of the optical conductor elements in relation to each other, but also movements perpendicular thereto, that is to say perpendicular to the plane of the chip or away from the chip. These movements are undesired, since they lead to an increase in the attenuation at the input coupling point. The undesired movements may be prevented, at least partially, by means of fixing the free end of the variable-length element, but the fixing has to be configured in such a way that the desired temperature-dependent movement is permitted.

[0011] It has already been proposed to provide a displaceable guide on the other holding block. However, this type of fixing requires very close machining tolerances of the components and a great deal of precision mechanical effort. Nevertheless, problems arise as a result of friction and play in the guide.

SUMMARY OF THE INVENTION

[0012] By contrast, the invention provides an optical coupling device in which movements of the end face of the optical fibre which movements are perpendicular to this face are suppressed and, at the same time, the desired movement of the end face of this optical fibre parallel to the end face of another optical fiber or waveguide such as a planar waveguide, is permitted. In particular, an optimal coupling device is to be provided which is compatible with the established manufacturing and adhesive bonding methods and permits adjustment of the input coupling point before adhesive bonding.

[0013] Further, the optical coupling device mentioned in the Field of the Invention contains, among other elements, a variable-length element which is connected to a variable-length compensating element, whose length changes with the temperature by the same amount but in the opposite sense as that of the variable-length element, and in that the variable-length compensating element is fixed to a second holding block.

[0014] The variable-length element, which can consist of aluminium, for example, in this embodiment of the invention is lengthened by a compensating element made of a material with a negative coefficient of expansion, so that the result overall is the same thermal

expansion as in the carrier material, for example quartz glass. As a result, although the input coupling fibre is shifted in the desired manner, that is to say the end face of the input coupling fibre moves parallel to the input coupling face of the chip, no relative movement takes place between the fixing points of the two holding blocks and the carrier material, that is to say the chip, since the total length of the variable-length element and variable-length compensating element is always of the same size. Therefore, the stresses and shifts described above are minimized.

[0015] A further advantageous refinement of the device according to the invention is that the length of the variable-length compensating element is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element changes by the same amount but in the opposite sense or amount as that of the variable-length element. In other words, only the combination of the influences of the length of the compensating element and its coefficient of expansion matters, so that accurate matching of the coefficient of expansion is not necessary.

[0016] In the optical coupling device first mentioned in the Field of the Invention, the holding block has a U-shaped part made of a material with the same coefficient of thermal expansion as the chip, in that a T-shaped part made of a material with the same coefficient of thermal expansion as the chip is provided, and in that the variable-length element with the positive coefficient of thermal expansion is connected to the T-shaped part at its foot and to the U-shaped part at its base, and in that two variable-length elements with a positive coefficient of thermal expansion are fixed to the legs of the U-shaped part, which consist of the same material as the variable-length element and have the same length as the latter, and which, on one side, are fixed to the legs of the U-shaped part and, on the other side, to the underside of the crossbar of the T-shaped part. This coupling device is fixed or adhesively bonded to the chip with the aid of the U-shaped part. By means of the identical thermal expansions of the three columns formed by the variable-length elements and the U-shaped and the T-shaped part, permanent adhesive bonding of the individual parts is made possible, without the connection points being stressed as a result of temperature expansions. Therefore, the input coupling fibre can advantageously carry out the desired temperature-dependent movements. As a result of the additional parts, the desired fixing of the upper end of the variable-length element is achieved, so that temperature-dependent and time-dependent changes in the adhesive bonding point between the U-shaped part and the variable-length elements can have only a minimal effect. Only the U-shaped part is connected or adhesively bonded to the chip, and all the other parts can move freely and, therefore, are able to shift in the event of fluctuating temperatures and corresponding expansion of the variable-length elements with a positive coefficient of thermal expansion.

[0017] A further advantageous refinement of the device according to the invention is that the variable-length elements consist of aluminium which, because of its material characteristics, is preferred for this purpose.

[0018] Finally, a further advantageous refinement of the device according to the invention is that the material of the variable-length compensating elements is a glass ceramic with a negative coefficient of thermal expansion, preferably the material of the chip. This achieves a minimum influence of temperature changes between chip and holding block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Exemplary embodiments of the invention will be described by using the appended drawings, in which:

[0020] Fig. 1 shows a side view of a coupling device according to a first exemplary embodiment of the invention;

[0021] Fig. 2 shows a plan view of a second exemplary embodiment of the coupling device according to the invention with the viewing direction in accordance with the arrow B in Figure 3; and

[0022] Fig. 3 shows a side view of the second exemplary embodiment of the coupling device according to the invention.

[0023] Figure 1 shows an optical waveguide chip 2 (also commonly known as a planar waveguide) on which, via two holding blocks 4, 6 (for example glass or glass ceramic), a variable-length element 8 made of aluminium, a variable-length compensating element 10 made of a material with a negative coefficient of thermal expansion and a ferrule 12 are held, by means of which an optical fibre 14 is held in an input coupling position on the optical waveguide chip 2. The ferrule 12 moves in the direction of the double arrow P.

[0024] In this embodiment, in other words, the variable-length element 8 is lengthened by means of a variable-length compensating element 10, so that overall, the result is the same thermal expansion as in the case of the carrier material of the optical waveguide chip, for example, quartz glass. This means that, in the event of temperature changes, the input coupling fibre is shifted in the desired way in order to compensate for the centre wavelength, but that no relative movement takes place between the fixing points of the holding blocks 4, 6

and the optical waveguide chip 2.

[0025] Possible glass ceramic materials which have a negative coefficient of thermal expansion can be obtained under the names ROBAX® or CERODUR®. Since the magnitudes of the coefficients of expansion of these materials, as compared with the coefficient of thermal expansion of the variable-length element 8 made of aluminium, are different, the length of the compensating element 10 is matched in such a way that, overall, the result is thermal expansion as in the case of the carrier material, quartz glass.

[0026] On the side of the optical waveguide chip 2 located opposite the input coupling side, the output coupling fibres 16 are illustrated.

[0027] Figures 2 and 3 show a plan view and a side view, respectively, of a second exemplary embodiment of the coupling device according to the invention, Figure 2 having to be viewed in the viewing direction of the arrow B of Figure 3. In this exemplary embodiment, a U-shaped part 22 is provided as a holding block belonging to the coupling device on an optical waveguide chip 20. Fixed to the base 24 of the U-shaped part is a first variable-length element 26, which carries the ferrule 28 in which the fibre 30 is fixed. The other end of the variable-length element 26 is fixed to the foot 30 of a T-shaped part 32. Two second variable-length elements 34, 36 are fixed to the underside 38 of the crossbar 40 of the T-shaped element 32 and, on the other side, to the ends of legs 40, 42 of the U-shaped part 22. In this exemplary embodiment, the variable-length parts 26, 34, 36 are made of aluminium, which has a positive coefficient of thermal expansion, and the T-shaped part 32 and the U-shaped part 33 are made of glass ceramic, preferably of the same material as the optical waveguide chip 20, the said material having the same coefficient of thermal expansion as the optical waveguide chip.

[0028] This construction results in three “columns”, which in each case consist half of aluminium and half of glass material. As a result, all three “columns” in each case exhibit the same overall temperature expansion. Permanent adhesive bonding of the individual parts is therefore possible, without the connecting points being stressed as a result of temperature expansion. By means of the additional parts, the desired fixing of the upper end of the variable-length element 26 is achieved, so that temperature-dependent and time-dependent changes in the bonding point between the U-shaped part 22 and the variable-length element 26 no longer have any effect. Only the U-shaped parts 22 is connected to the optical waveguide chip 20 or adhesively bonded thereto. All the other parts of the coupling device can move freely and can therefore shift in the event of expansion of the variable-length elements corresponding to fluctuating temperatures. Output coupling fibres 46 are again

shown on the output coupling side of the optical waveguide chip 20.

Patent claims

PCT Amended Sheets

1. An optical coupling device for coupling light between two optical waveguide end faces, said device comprising:

    two optical waveguides having end faces,

    a variable-length element which carries one of the two optical waveguides via a holding element and is fixed to the other optical waveguide by at least one holding block;

    a variable-length compensating element which is connected to the variable-length element, and is fixed to a second holding block;

    wherein the length of the variable-length compensating element changes with temperature by the same amount, but in the opposite sense, as that of the variable-length element; and

    wherein the geometric position of one optical waveguide end face is capable of being varied with respect to the other optical waveguide end face by movement of the variable-length element.

2. The coupling device according to Claim 1, wherein the length of the variable-length compensating element is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element changes by the same amount but in the opposite sense as that of the variable-length element.

3. The optical coupling device according to Claim 1, wherein the variable-length element is made of aluminium.

4. The optical coupling device according to Claim 2, wherein the variable-length element is made of aluminium.

5. The coupling device according to Claim 1, wherein the material of the variable-length compensating element is a glass ceramic.

6. The coupling device according to Claim 2, wherein the material of the variable-length compensating element is a glass ceramic.

7. The coupling device according to Claim 3, wherein the material of the variable-length compensating element is a glass ceramic.

8. The coupling device according to Claim 4, wherein the material of the variable-length compensating element is a glass ceramic.

9. The optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip, with the aid of a variable-length element, said coupling device comprising:

a variable-length element which carries one of the two optical waveguides via a holding element and is fixed to the other optical waveguide by means of at least one holding block, wherein the holding block has a U-shaped part made of a material with the same coefficient of thermal expansion as the other optical waveguide, and further in that a T-shaped part made of a material with the same coefficient of thermal expansion as the other optical waveguide is provided, wherein further that the variable-length element with the positive coefficient of thermal expansion is connected to the T-shaped part at its foot and to the U-shaped part at its base, and wherein further in that two variable-length elements with a positive coefficient of thermal expansion are fixed to the legs of the U-shaped part, which consist of the same material as the variable-length element and have the same length as the latter and which, on one side, are fixed to the legs of the U-shaped part and, on the other side, to the underside of the crossbar of the T-shaped part.

10. The coupling device according to Claim 9, wherein the variable-length elements consist of aluminium.

11. The coupling device according to Claim 5, wherein the material of the U-shaped part and of the T-shaped part is a glass ceramic with the same coefficient of thermal expansion as the other optical waveguide.

12. The coupling device according to Claim 11, wherein the material of the U-shaped part

and the material of the T-shaped part is the same as the other optical waveguide.

Abstract of the Invention

An optical coupling device for coupling light in between two optical waveguide end faces, in which the geometric position of one optical waveguide end face can be varied with respect to the other optical waveguide end face with the aid of a variable-length element. The element carries one of the two optical waveguides, and is connected to the other optical waveguide via a holding block. The variable-length element is connected to a variable-length compensating element, whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element. The variable-length compensating element is fixed to the second holding block.

VERSION OF APPLICATION WITH MARKINGS TO SHOW CHANGES MADE

SI01-013

OPTICAL COUPLING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of German Patent Application No. 19934185.0 filed July 21, 1999, and is a national stage filing under 35 U.S.C. § 371 of PCT Application PCT/DE00/02399, filed July 21, 2000.

FIELD OF THE INVENTION

[0002] The invention relates to an optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of a strip conductor of an optical component, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding [device] element and is connected to the structure containing the other optical waveguide, or is fixed to said structure, by means of at least one holding block.

BACKGROUND OF THE INVENTION

[0003] An optical coupling device is disclosed, for example, by WO 98/13718. Coupling devices of this type are used in optical filters based on the phased-array principle having an input coupling face which light enters at a specific geometric position, the geometric position influencing the output wavelength of the optical filter. Optical filters based on the phased-array principle are used in particular as multiplexers or demultiplexers in optical wavelengths multiplex operation (WDM), since they exhibit low insertion attenuation and high crosstalk suppression.

[0004] German patent application DE 44 22 651.9 describes how the centre wavelength of a phased-array filter can be defined by the position of an input coupling optical waveguide which leads the light into the optical waveguide. In this way, the centre wavelength of the optical filter can be adjusted exactly by means of the geometric positioning of the input coupling optical waveguide or the input coupling fibre.

[0005] Optical coupling devices are also used in narrow-band wavelength multiplexers (DWDM) for optical waveguide transmission technology. These components make it possible, on the transmitter side, to combine the signals from lasers of various wavelengths with low losses onto a single glass fibre or, respectively, on the receiver side, to divide said

signals to a corresponding number of receivers in a wavelength-selective manner.

[0005] The particular advantage of narrow-band wavelength multiplexers as compared with conventional wavelength multiplexers lies in their narrow-band nature. As a result, such a small channel spacing is possible that, at the minimum attenuation of the glass fibre, that is to say in the wavelength range around 1550 nm, a large number of transmission channels, for example 32 transmission channels, can be accommodated. A DWDM comprises a chip, to which waveguide structures with the necessary geometry are applied. On the receiver side, the input of the chip is the fibre with the multiplexer signal, which is also referred to as the input coupling fibre. On the output coupling side, a corresponding number of fibres are fitted, which lead the individual signals on to the receiver.

[0006] In optical waveguide transmission technology with DWDM, the problem is that the characteristics of the chip change sharply with the operating temperature. A temperature change leads to a change in the refractive index relationships and also the geometric relationships of the chips. As a result, wavelength shifts occur, that is to say the branch of the channel between DWDM and the lasers and, respectively, between the transmitter side and the receiver side is shifted. For this reason, the shift in the centre wavelengths must be avoided.

[0007] In order to avoid the temperature effects described, passive temperature compensation has already been proposed. The temperature dependence of the centre wavelength can be compensated for by the fact that the input coupling fibre is shifted vertically with respect to the DWDM chip as a function of the temperature. This shift is carried out by means of a variable-length component which, as compared with the carrier material of the chip, has a higher thermal coefficient of expansion, for example by means of a variable-length element made of aluminium. Then, as was described at the beginning, the optical fibre is fixed to the variable-length element, so that the end faces of the optical fibre and of the optical conductor chip <u>(also called a planar waveguide or a planar waveguide chip)</u> are shifted parallel to one another, which compensates for the influence of the temperature on the centre wavelength.

[0008] In the practical implementation of this coupling device, the connecting points between the holding block and the chip, on the one hand, and the holding block and the variable-length element, on the other hand, are designed using adhesive bonding technology. In this case, the bonding point between the holding block and the chip is cured after the input coupling fibre has been positioned optically relative to the chip.

[0009] In the case of this technology, the problem arises that the bonded connections are subject to temperature-dependent changes. As a result of different bond gap widths, inhomogeneities and gassing-out of the adhesive, mechanical stresses arise in the gap. This is particularly critical in the case of bonded connections between materials with different coefficients of thermal expansion, such as aluminium and glass or glass ceramic. The consequence of the thermally inducted stresses is that a temperature change not only affects the desired movement of the end faces of the optical conductor elements in relation to each other, but also movements perpendicular thereto, that is to say perpendicular to the plane of the chip or away from the chip. These movements are undesired, since they lead to an increase in the attenuation at the input coupling point. The undesired movements may be prevented, at least partially, by means of fixing the free end of the variable-length element, but the fixing has to be configured in such a way that the desired temperature-dependent movement is permitted.

[0010] It has already been proposed to provide a displaceable guide on the other holding block. However, this type of fixing requires very close machining tolerances of the components and a great deal of precision mechanical effort. Nevertheless, problems arise as a result of friction and play in the guide.

SUMMARY OF THE INVENTION

[0011] By contrast, the invention [is based on the object of providing] provides an optical coupling device in which movements of the end face of the optical fibre which movements are perpendicular to this face are suppressed and, at the same time, the desired movement of the end [faces] face of this optical fibre parallel to [each other] the end face of another optical fiber or waveguide such as a planar waveguide, is permitted. In particular, an optimal coupling device is to be provided which is compatible with the established manufacturing and adhesive bonding methods and permits adjustment of the input coupling point before adhesive bonding.

[0012] [In order to achieve the object,] Further, the optical coupling device mentioned [at the beginning is characterized in that the] in the Field of the Invention contains, among other elements, a variable-length element which is connected to a variable-length compensating element, whose length changes with the temperature by the same amount but in the opposite sense as that of the variable-length element, and in that the variable-length compensating element is fixed to a second holding block.

[0013] The variable-length element, which can consist of aluminium, for example, in this

embodiment of the invention is lengthened by a compensating element made of a material with a negative coefficient of expansion, so that the result overall is the same thermal expansion as in the carrier material, for example quartz glass. As a result, although the input coupling fibre is shifted in the desired manner, that is to say the end face of the input coupling fibre moves parallel to the input coupling face of the chip, no relative movement takes place between the fixing points of the two holding blocks and the carrier material, that is to say the chip, since the total length of the variable-length element and variable-length compensating element is always of the same size. Therefore, the stresses and shifts described above are minimized.

[0014] A further advantageous refinement of the device according to the invention is [characterized in] that the length of the variable-length compensating element is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element changes by the same amount but in the opposite sense <u>or amount</u> as that of the variable-length element. In other words, only the combination of the influences of the length of the compensating element and its coefficient of expansion matters, so that accurate matching of the coefficient of expansion is not necessary.

[0015] [In order to achieve the object mentioned above,] <u>In</u> the optical coupling <u>device first</u> mentioned [at the beginning is characterized in that] <u>in the Field of the Invention,</u> the holding block has a U-shaped part made of a material with the same coefficient of thermal expansion as the chip, in that a T-shaped part made of a material with the same coefficient of thermal expansion as the chip is provided, <u>and</u> in that the variable-length element with the positive coefficient of thermal expansion is connected to the T-shaped part at its foot and to the U-shaped part at its base, and in that two variable-length elements with a positive coefficient of thermal expansion are fixed to the legs of the U-shaped part, which consist of the same material as the variable-length element and have the same length as the latter, and which, on one side, are fixed to the legs of the U-shaped part and, on the other side, to the underside of the crossbar of the T-shaped part. This coupling device is fixed or adhesively bonded to the chip with the aid of the U-shaped part. By means of the identical thermal expansions of the three columns formed by the variable-length elements and the U-shaped and the T-shaped part, permanent adhesive bonding of the individual parts is made possible, without the connection points being stressed as a result of temperature expansions. Therefore, the input coupling fibre can advantageously carry out the desired temperature-dependent movements. As a result of the additional parts, the desired fixing of the upper end of the variable-length element is achieved, so that temperature-dependent and time-dependent changes in the adhesive bonding point between the U-shaped part and the variable-length elements can have only a minimal effect. Only the U-shaped part is connected or adhesively bonded to the chip,

and all the other parts can move freely and, therefore, are able to shift in the event of fluctuating temperatures and corresponding expansion of the variable-length elements with a positive coefficient of thermal expansion.

[0016] A further advantageous refinement of the device according to the invention is [characterized in] that the variable-length elements consist of aluminium which, because of its material characteristics, is preferred for this purpose.

[0017] Finally, a further advantageous refinement of the device according to the invention is [characterized in] that the material of the variable-length compensating elements is a glass ceramic with a negative coefficient of thermal expansion, preferably the material of the chip. This achieves a minimum influence of temperature changes between chip and holding block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Exemplary embodiments of the invention will be described by using the appended drawings, in which:

[0019] Fig. 1 shows a side view of a coupling device according to a first exemplary embodiment of the invention;

[0020] Fig. 2 shows a plan view of a second exemplary embodiment of the coupling device according to the invention with the viewing direction in accordance with the arrow B in Figure 3; and

[0021] Fig. 3 shows a side view of the second exemplary embodiment of the coupling device according to the invention.

[0022] Figure 1 shows an optical waveguide chip 2 (also commonly known as a planar waveguide) on which, via two holding blocks 4, 6 (for example glass or glass ceramic), a variable-length element 8 made of aluminium, a variable-length compensating element 10 made of a material with a negative coefficient of thermal expansion and a ferrule 12 are held, by means of which an optical fibre 14 is held in an input coupling position on the optical waveguide chip 2. The ferrule 12 moves in the direction of the double arrow P.

[0023] In this embodiment, in other words, the variable-length element 8 is lengthened by means of a variable-length compensating element 10, so that overall, the result is the same thermal expansion as in the case of the carrier material of the optical waveguide chip,

[namely in the case of] for example, quartz glass. This means that, in the event of temperature changes, the input coupling fibre is shifted in the desired way in order to compensate for the centre wavelength, but that no relative movement takes place between the fixing points of the holding blocks 4, 6 and the optical waveguide chip 2.

[0024] Possible glass ceramic materials which have a negative coefficient of thermal expansion can be obtained under the names ROBAX® or CERODUR®. Since the magnitudes of the coefficients of expansion of these materials, as compared with the coefficient of thermal expansion of the variable-length element 8 made of aluminium, are different, the length of the compensating element 10 is matched in such a way that, overall, the result is thermal expansion as in the case of the carrier material, quartz glass.

[0025] On the side of the optical waveguide chip 2 located opposite the input coupling side, the output coupling fibres 16 are illustrated.

[0026] Figures 2 and 3 show a plan view and a side view, respectively, of a second exemplary embodiment of the coupling device according to the invention, Figure 2 having to be viewed in the viewing direction of the arrow B of Figure 3. In this exemplary embodiment, a U-shaped part 22 is provided as a holding block belonging to the coupling device on an optical waveguide chip 20. Fixed to the base 24 of the U-shaped part is [the] a first variable-length element 26, which carries the ferrule 28 in which the fibre 30 is fixed. The other end of the variable-length element 26 is fixed to the foot 30 of a T-shaped part 32. Two [further] second variable-length elements 34, 36 are fixed to the underside 38 of the crossbar 40 of the T-shaped element 32 and, on the other side, to the ends of legs 40, 42 of the U-shaped part 22. In this exemplary embodiment, the variable-length parts 26, 34, 36 are made of aluminium, which has a positive coefficient of thermal expansion, and the T-shaped part 32 and the U-shaped part 33 are made of glass ceramic, preferably of the same material as the optical waveguide chip 20, the said material having the same coefficient of thermal expansion as the optical waveguide chip.

[0027] This construction results in three “columns”, which in each case consist half of aluminium and half of glass material. As a result, all three “columns” in each case exhibit the same overall temperature expansion. Permanent adhesive bonding of the individual parts is therefore possible, without the connecting points being stressed as a result of temperature expansion. By means of the additional parts, the desired fixing of the upper end of the variable-length element 26 is achieved, so that temperature-dependent and time-dependent changes in the bonding point between the U-shaped part 22 and the variable-length element 26 no longer have any effect. Only the U-shaped parts 22 is connected to the optical

waveguide chip 20 or adhesively bonded thereto. All the other parts of the coupling device can move freely and can therefore shift in the event of expansion of the variable-length elements corresponding to fluctuating temperatures. Output coupling fibres 46 are again shown on the output coupling side of the optical waveguide chip 20.

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Patent Claims

[1. Optical coupling device for injecting light between two optical waveguide end faces, the geometric position of the one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding device and is fixed to the other optical waveguide by means of at least one holding block, characterized in that the variable-length element (8) is connected to a variable-length compensating element (10), whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element (8), and in that the variable–length compensating element (10) is fixed to a second holding block (6).]

[2. Coupling device according to Claim 1, characterized in that the length of the variable-length compensating element (10) is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element (6) changes by the same amount but in the opposite sense as that of the variable-length element.]

[3. Optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding device and is fixed to the other optical waveguide by means of at least one holding block, characterized in that the holding block has a U-shaped part (22) made of a material with the same coefficient of thermal expansion as the chip, in that a T-shaped part (32) made of a material with the same coefficient of thermal expansion as the chip is provided, in that the variable-length element (26) with the positive coefficient of thermal expansion is connected to the T-shaped part (32) at its foot (30) and to the U-shaped part at its base, and in that two variable-length elements (34, 36) with a positive coefficient of thermal expansion are fixed to the legs (40, 42) of the U-shaped part (22), which consist of the same material as the variable-length element (26) and have the same length as the latter and which, on one side, are fixed to the legs of the U-shaped part (22) and, on the other side, to the underside (38) of the crossbar (40) of the T-shaped part (32).]

[4. Coupling device according to one of Claims 1 to 3, characterized in that the variable-length elements consist of aluminium.]

[5. Coupling device according to one of Claims 1 to 4, characterized in that the material of the variable-length compensating elements is a glass ceramic with the same coefficient of thermal expansion, preferably the material of the chip.]

Patent claims

PCT Amended Sheets

1. [Optical coupling device for coupling light in between two optical waveguide end faces, the geometric position of the one optical waveguide end face, for example of an optical fibre (14), being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip (2), with the aid of a variable-length element (8), which carries one of the two optical waveguides via a holding device and is fixed to the other optical waveguide by means of at least one holding block (4), characterized in that the variable-length element (8) is connected to a variable-length compensating element (10), whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element (8), and in that the variable–length compensating element (10) is fixed to another holding block (6).] An optical coupling device for coupling light between two optical waveguide end faces, said device comprising:

two optical waveguides having end faces,

a variable-length element which carries one of the two optical waveguides via a holding element and is fixed to the other optical waveguide by at least one holding block;

a variable-length compensating element which is connected to the variable-length element, and is fixed to a second holding block;

wherein the length of the variable-length compensating element changes with temperature by the same amount, but in the opposite sense, as that of the variable-length element; and

wherein the geometric position of one optical waveguide end face is capable of being varied with respect to the other optical waveguide end face by movement of the variable-length element.

2. [Coupling] <u>The coupling</u> device according to Claim 1, [characterized in that] <u>wherein</u> the length of the variable-length compensating element [(10)] is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element [(6)] changes by the same amount but in the opposite sense as that of the variable-length element [(8)].

3. [Optical] The optical coupling device according to Claim 1 [or 2], [characterized in that] wherein the variable-length element [(8)] is made of aluminium.

4. The optical coupling device according to Claim 2, wherein the variable-length element is made of aluminium.

5. [Coupling] The coupling device according to [one of Claims 1 to 3] Claim 1, [characterized in that] wherein the material of the variable-length compensating element [(10)] is a glass ceramic.

6. The coupling device according to Claim 2, wherein the material of the variable-length compensating element is a glass ceramic.

7. The coupling device according to Claim 3, wherein the material of the variable-length compensating element is a glass ceramic.

8. The coupling device according to Claim 4, wherein the material of the variable-length compensating element is a glass ceramic.

9. [Optical] The optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre [(14)], being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip [(2)], with the aid of a variable-length element [(26)], said coupling device comprising:

a variable-length element which carries one of the two optical waveguides via a holding [device] element and is fixed to the other optical waveguide by means of at least one holding block, [characterized in that] wherein the holding block has a U-shaped part [(22)] made of a material with the same coefficient of thermal expansion as the other optical waveguide, and further in that a T-shaped part [(32)] made of a material with the same coefficient of thermal expansion as the other optical waveguide is provided, [in] wherein further that the variable-length element [(26)]

with the positive coefficient of thermal expansion is connected to the T-shaped part [(32)] at its foot [(30)] and to the U-shaped part [(22)] at its base [(24)], and wherein further in that two variable-length elements [(34, 36)] with a positive coefficient of thermal expansion are fixed to the legs [(40, 42)] of the U-shaped part [(22)], which consist of the same material as the variable-length element [(26)] and have the same length as the latter and which, on one side, are fixed to the legs [(40, 42)] of the U-shaped part [(22)] and, on the other side, to the underside [(38)] of the crossbar [(4)] of the T-shaped part [(32)].

10. [Coupling] The coupling device according to Claim [5] 9, [characterized in that] wherein the variable-length elements [(26, 34, 36)] consist of aluminium.

11. [Coupling] The coupling device according to Claim 5 [or 6], [characterized in that] wherein the material of the U-shaped part [(22)] and of the T-shaped part [(32)] is a glass ceramic with the same coefficient of thermal expansion as the other optical waveguide. [, preferably the same as the material of the other optical waveguide.]

12. The coupling device according to Claim 11, wherein the material of the U-shaped part and the material of the T-shaped part is the same as the other optical waveguide.

Abstract of the Invention

[Optical coupling device]

An optical coupling device for coupling light in between two optical waveguide end faces, in which the geometric position of one optical waveguide end face can be varied with respect to the other optical waveguide end face with the aid of a variable-length element. The element carries one of the two optical waveguides, and is connected to the other optical waveguide via a holding block [(4)]. The variable-length element [(8)] is connected to a variable-length compensating element [(10)], whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element [(8)]. The variable-length compensating element [(10)] is fixed to the second holding block [(6)].

[Fig. 1]

FIG 1

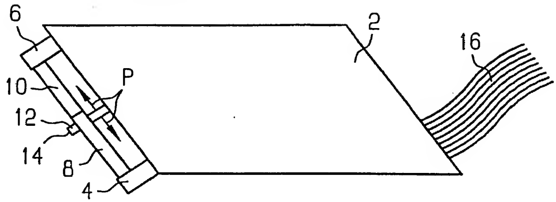


FIG 2

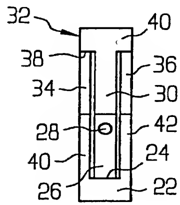
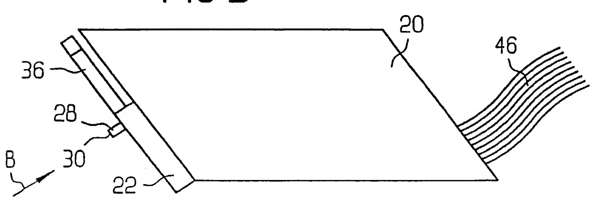


FIG 3



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Original Translation

Description

Optical coupling device

The invention relates to an optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of a strip conductor of an optical component, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding device and is connected to the structure containing the other optical waveguide, or is fixed to said structure, by means of at least one holding block.

An optical coupling device is disclosed, for example, by WO 98/13718. Coupling devices of this type are used in optical filters based on the phased-array principle having an input coupling face which light enters at a specific geometric position, the geometric position influencing the output wavelength of the optical filter. Optical filters based on the phased-array principle are used in particular as multiplexers or demultiplexers in optical wavelengths multiplex operation (WDM), since they exhibit low insertion attenuation and high crosstalk suppression.

German patent application DE 44 22 651.9 describes how the centre wavelength of a phased-array filter can be defined by the position of an input coupling optical waveguide which leads the light into the optical waveguide. In this way, the centre wavelength of the optical filter can be adjusted exactly by means of the geometric positioning of the input coupling optical waveguide or the input coupling fibre.

Optical coupling devices are also used in narrow-band wavelength multiplexers (DWDM) for optical waveguide transmission technology. These components make it possible, on the transmitter side, to combine the signals from lasers of various wavelengths with low losses onto a single glass fibre or, respectively, on the receiver side, to divide said signals to a corresponding number of receivers in a wavelength-selective manner.

The particular advantage of narrow-band wavelength multiplexers as compared with conventional wavelength multiplexers lies in their narrow-band nature. As a result, such a small channel spacing is possible that, at the minimum attenuation of the glass fibre, that is to say in the wavelength range around 1550 nm, a large number of transmission channels, for example 32 transmission channels, can be accommodated. A DWDM comprises a chip, to which waveguide structures with the necessary geometry are applied. On the receiver side, the input of the chip is the fibre with the multiplexer signal, which is also referred to as the input coupling fibre. On the output coupling side, a corresponding number of fibres are fitted, which lead the individual signals on to the receiver.

In optical waveguide transmission technology with DWDM, the problem is that the characteristics of the chip change sharply with the operating temperature. A temperature change leads to a change in the refractive index relationships and also the geometric relationships of the chips. As a result, wavelength shifts occur, that is to say the branch of the channel between DWDM and the lasers and, respectively, between the transmitter side and the receiver side is shifted. For this reason, the shift in the centre wavelengths must be avoided.

In order to avoid the temperature effects described, passive temperature compensation has already been proposed. The temperature dependence of the centre wavelength can be compensated for by the fact that the input coupling fibre is shifted vertically with respect to the DWDM chip as a function of the temperature. This shift is carried out by means of a variable-length component which, as compared with the carrier material of the chip, has a higher thermal coefficient of expansion, for example by means of a variable-length element made of aluminium. Then, as was described at the beginning, the optical fibre is fixed to the variable-length element, so that the end faces of the optical fibre and of the optical conductor chip are shifted parallel to one another, which compensates for the influence of the temperature on the centre wavelength.

In the practical implementation of this coupling device, the connecting points between the holding block and the chip, on the one hand, and the holding block and the variable-length element, on the other hand, are designed using adhesive bonding technology. In this case, the bonding point between the holding block and the chip is cured after the input coupling fibre has been positioned optically relative to the chip.

In the case of this technology, the problem arises that the bonded connections are subject to temperature-dependent changes. As a result of different bond gap widths, inhomogeneities and gassing-out of the adhesive, mechanical stresses arise in the gap. This is particularly critical in the case of bonded connections between materials with different coefficients of thermal expansion, such as aluminium and glass or glass ceramic. The consequence of the thermally inducted stresses is that a temperature change not only affects the desired movement of the end faces of the optical conductor elements in relation to each other, but also

movements perpendicular thereto, that is to say perpendicular to the plane of the chip or away from the chip. These movements are undesired, since they lead to an increase in the attenuation at the input coupling point. The undesired movements may be prevented, at least partially, by means of fixing the free end of the variable-length element, but the fixing has to be configured in such a way that the desired temperature-dependent movement is permitted.

It has already been proposed to provide a displaceable guide on the other holding block. However, this type of fixing requires very close machining tolerances of the components and a great deal of precision mechanical effort. Nevertheless, problems arise as a result of friction and play in the guide.

By contrast, the invention is based on the object of providing an optical coupling device in which movements of the end face of the optical fibre perpendicular to this face are suppressed and, at the same time, the desired movement of the end faces parallel to each other is permitted. In particular, an optimal coupling device is to be provided which is compatible with the established manufacturing and adhesive bonding methods and permits adjustment of the input coupling point before adhesive bonding.

In order to achieve the object, the optical coupling device mentioned at the beginning is characterized in that the variable-length element is connected to a variable-length compensating element, whose length changes with the temperature by the same amount but in the opposite sense as that of the variable-length element, and in that the variable-length compensating element is fixed to a second holding block.

The variable-length element, which can consist of aluminium, for example, in this embodiment of the

invention is lengthened by a compensating element made of a material with a negative coefficient of expansion, so that the result overall is the same thermal expansion as in the carrier material, for example quartz glass. As a result, although the input coupling fibre is shifted in the desired manner, that is to say the end face of the input coupling fibre moves parallel to the input coupling face of the chip, no relative movement takes place between the fixing points of the two holding blocks and the carrier material, that is to say the chip, since the total length of the variable-length element and variable-length compensating element is always of the same size. Therefore, the stresses and shifts described above are minimized.

A further advantageous refinement of the device according to the invention is characterized in that the length of the variable-length compensating element is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element changes by the same amount but in the opposite sense as that of the variable-length element. In other words, only the combination of the influences of the length of the compensating element and its coefficient of expansion matters, so that accurate matching of the coefficient of expansion is not necessary.

In order to achieve the object mentioned above, the optical coupling mentioned at the beginning is characterized in that the holding block has a U-shaped part made of a material with the same coefficient of thermal expansion as the chip, in that a T-shaped part made of a material with the same coefficient of thermal expansion as the chip is provided, in that the variable-length element with the positive coefficient of thermal expansion is connected to the T-shaped part at its foot and to the U-shaped part at its base, and in that two variable-length elements with a positive

coefficient of thermal expansion are fixed to the legs of the U-shaped part, which consist of the same material as the variable-length element and have the same length as the latter, and which, on one side, are fixed to the legs of the U-shaped part and, on the other side, to the underside of the crossbar of the T-shaped part. This coupling device is fixed or adhesively bonded to the chip with the aid of the U-shaped part. By means of the identical thermal expansions of the three columns formed by the variable-length elements and the U-shaped and the T-shaped part, permanent adhesive bonding of the individual parts is made possible, without the connection points being stressed as a result of temperature expansions. Therefore, the input coupling fibre can advantageously carry out the desired temperature-dependent movements. As a result of the additional parts, the desired fixing of the upper end of the variable-length element is achieved, so that temperature-dependent and time-dependent changes in the adhesive bonding point between the U-shaped part and the variable-length elements can have only a minimal effect. Only the U-shaped part is connected or adhesively bonded to the chip, and all the other parts can move freely and, therefore, are able to shift in the event of fluctuating temperatures and corresponding expansion of the variable-length elements with a positive coefficient of thermal expansion.

A further advantageous refinement of the device according to the invention is characterized in that the variable-length elements consist of aluminium which, because of its material characteristics, is preferred for this purpose.

Finally, a further advantageous refinement of the device according to the invention is characterized in that the material of the variable-length compensating elements is a glass ceramic with a negative coefficient of thermal expansion, preferably the material of the

chip. This achieves a minimum influence of temperature changes between chip and holding block.

Exemplary embodiments of the invention will be described by using the appended drawings, in which:

Fig. 1 shows a side view of a coupling device according to a first exemplary embodiment of the invention;

Fig. 2 shows a plan view of a second exemplary embodiment of the coupling device according to the invention with the viewing direction in accordance with the arrow B in Figure 3; and

Fig. 3 shows a side view of the second exemplary embodiment of the coupling device according to the invention.

Figure 1 shows an optical waveguide chip 2 on which, via two holding blocks 4, 6 (for example glass or glass ceramic), a variable-length element 8 made of aluminium, a variable-length compensating element 10 made of a material with a negative coefficient of thermal expansion and a ferrule 12 are held, by means of which an optical fibre 14 is held in an input coupling position on the optical waveguide chip 2. The ferrule 12 moves in the direction of the double arrow P.

In this embodiment, in other words, the variable-length element 8 is lengthened by means of a variable-length compensating element 10, so that overall, the result is the same thermal expansion as in the case of the carrier material of the optical waveguide chip, namely in the case of quartz glass. This means that, in the event of temperature changes, the input coupling fibre is shifted in the desired way in order to compensate for the centre wavelength, but that no relative movement takes place between the fixing points of the holding blocks 4, 6 and the optical waveguide chip 2.

Possible glass ceramic materials which have a negative coefficient of thermal expansion can be obtained under the names ROBAX® or CERODUR®. Since the magnitudes of the coefficients of expansion of these materials, as compared with the coefficient of thermal expansion of the variable-length element 8 made of aluminium, are different, the length of the compensating element 10 is matched in such a way that, overall, the result is thermal expansion as in the case of the carrier material, quartz glass.

On the side of the optical waveguide chip 2 located opposite the input coupling side, the output coupling fibres 16 are illustrated.

Figures 2 and 3 show a plan view and a side view, respectively, of a second exemplary embodiment of the coupling device according to the invention, Figure 2 having to be viewed in the viewing direction of the arrow B of Figure 3. In this exemplary embodiment, a U-shaped part 22 is provided as a holding block belonging to the coupling device on an optical waveguide chip 20. Fixed to the base 24 of the U-shaped part is the variable-length element 26, which carries the ferrule 28 in which the fibre 30 is fixed. The other end of the variable-length element 26 is fixed to the foot 30 of a T-shaped part 32. Two further variable-length elements 34, 36 are fixed to the underside 38 of the crossbar 40 of the T-shaped element 32 and, on the other side, to the ends of legs 40, 42 of the U-shaped part 22. In this exemplary embodiment, the variable-length parts 26, 34, 36 are made of aluminium, which has a positive coefficient of thermal expansion, and the T-shaped part 32 and the U-shaped part 33 are made of glass ceramic, preferably of the same material as the optical waveguide chip 20, the said material having the same coefficient of thermal expansion as the optical waveguide chip.

This construction results in three "columns", which in each case consist half of aluminium and half of glass material. As a result, all three "columns" in each case exhibit the same overall temperature expansion. Permanent adhesive bonding of the individual parts is therefore possible, without the connecting points being stressed as a result of temperature expansion. By means of the additional parts, the desired fixing of the upper end of the variable-length element 26 is achieved, so that temperature-dependent and time-dependent changes in the bonding point between the U-shaped part 22 and the variable-length element 26 no longer have any effect. Only the U-shaped parts 22 is connected to the optical waveguide chip 20 or adhesively bonded thereto. All the other parts of the coupling device can move freely and can therefore shift in the event of expansion of the variable-length elements corresponding to fluctuating temperatures. Output coupling fibres 46 are again shown on the output coupling side of the optical waveguide chip 20.

Patent Claims

1. Optical coupling device for injecting light between two optical waveguide end faces, the geometric position of the one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding device and is fixed to the other optical waveguide by means of at least one holding block, characterized in that the variable-length element (8) is connected to a variable-length compensating element (10), whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element (8), and in that the variable-length compensating element (10) is fixed to a second holding block (6).

2. Coupling device according to Claim 1, characterized in that the length of the variable-length compensating element (10) is selected, taking its coefficient of expansion into account, such that the length of the variable-length compensating element (6) changes by the same amount but in the opposite sense as that of the variable-length element.

3. Optical coupling device for injecting light between two optical waveguide end faces, the geometric position of one optical waveguide end face, for example of an optical fibre, being capable of being varied with respect to the other optical waveguide end face, for example of an optical waveguide chip, with the aid of a variable-length element, which carries one of the two optical waveguides via a holding device and is

fixed to the other optical waveguide by means of at least one holding block, characterized in that the holding block has a U-shaped part (22) made of a material with the same coefficient of thermal expansion as the chip, in that a T-shaped part (32) made of a material with the same coefficient of thermal expansion as the chip is provided, in that the variable-length element (26) with the positive coefficient of thermal expansion is connected to the T-shaped part (32) at its foot (30) and to the U-shaped part at its base, and in that two variable-length elements (34, 36) with a positive coefficient of thermal expansion are fixed to the legs (40, 42) of the U-shaped part (22), which consist of the same material as the variable-length element (26) and have the same length as the latter and which, on one side, are fixed to the legs of the U-shaped part (22) and, on the other side, to the underside (38) of the crossbar (40) of the T-shaped part (32).

4. Coupling device according to one of Claims 1 to 3, characterized in that the variable-length elements consist of aluminium.

5. Coupling device according to one of Claims 1 to 4, characterized in that the material of the variable-length compensating elements is a glass ceramic with the same coefficient of thermal expansion, preferably the material of the chip.

Abstract

Optical coupling device

An optical coupling device for coupling light in between two optical waveguide end faces, in which the geometric position of one optical waveguide end face can be varied with respect to the other optical waveguide end face with the aid of a variable-length element. The element carries one of the two optical waveguides, and is connected to the other optical waveguide via a holding block (4). The variable-length element (8) is connected to a variable-length compensating element (10), whose length changes with temperature by the same amount but in the opposite sense as that of the variable-length element (8). The variable-length compensating element (10) is fixed to the second holding block (6).

Fig. 1

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DECLARATION IN ORIGINAL APPLICATION **U.S. Attorney Docket No.: SI01-013**

MAIL DATE CANCELLED

As a below named inventor, I declare that:

My residence, Post Office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **OPTICAL COUPLING DEVICE**.

The specification of which (check only one item below):

☐ is attached hereto

☒ was filed as United States Application Serial No. 10/031,899 on 1/19/02 and was amended on (if applicable)

☐ was filed as PCT international application number , on , and was amended under PCT Article 19 on (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate or 365(a) of any PCT international application which designated at least one country other than the Unites States, listed below and have also identified below any foreign application for patent or inventor's certificate, on the same subject matter, having a filing date before that of the application on which priority is claimed:

☒ **Country:** Germany **Application No.:** 19934185.0 **Filing Date:** 7/21/99

☐ **NONE**

I hereby claim the benefit under Title 35 United States Code § 119(e) and § 120 of any United States application(s) or 365(c) of any PCT international application designating the United States listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code § 112, I acknowledge the duty to disclose material information as defined in Title 37 Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

☐	**Provisional No.:**	**Filed:**	**Status:**
☒	**Application No.:**	**Filed:**	**Status:**
	PCT Application No:DE00/02399	**Filed:** 7/21/00	**Status:** Pending
☐	**NONE**		

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DECLARATION IN ORIGINAL APPLICATION

MAIL DATE CANCELLED MAR 2 8 2002

OIPE MAY 0 2 2002 PATENT & TRADEMARK OFFICE

U.S. Attorney Docket No.: SI01-013

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

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